# A Magnetic Survey of Precambrian Greenstones and Cambrian Clastic Sedimentary Rocks of the Chilhowee Group, Blue Ridge Mountains, Virginia.

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## INTRODUCTION

The Blue Ridge Mountains extend more than 1000 kilometers from Georgia to Pennsylvania. The location of the magnetic survey conducted in this project is located approximately 10 kilometers east of Lexington, Virginia and is within the Blue Ridge complex. This complex is a northeast plunging anticlinorium containing a core of Grenville-age, high-grade gneisses which are flanked and overlain by a cover of late Precambrian and Paleozoic meta-sediments and meta-volcanics. The purpose of this research project was to determine whether magnetics is a viable tool for mapping on a small scale within the Blue Ridge Complex. Two traverses are compared in this study: (1) a transect from the Lynchburg reservoir area which is underlain by well exposed outcrops of Cotoctin greenstones and (2) a transect from the Beverlytown area which has generally poor exposures.

## ROCK UNITS

The primary rock units in the survey area are the Virginia Blue Ridge basement, the Swift Run, the Cotoctin Formation, and the Chilhowee Group, consisting of the Antietam Formation, the Harpers Formation and the Unicoi Formation. The basement rocks of the Virginia Blue Ridge consist of Precambrian granite, hypersthene granodiorite, charnokite and unakite. The Precambrian Swift Run Formation (0-120 m) contains primarily greywackes, sub-greywackes and volcanics. The Cotoctin Formation (0-300 m) consists of greenstone with greywackes, arkoses and tuffs, is Cambrian-Precambrian in age, and is associated with the initial rifting of the ancestral Atlantic Ocean at about 650-600 Ma. The Unicoi Formation, the oldest formation in the Chilhowee Group includes greywacke, sandstone and pebble conglomerate with a few tuffaceous beds. Overlaying the Unicoi is the Harpers Formation (300-500 m) with laminated shales, greywacke and quartzite. The Antietam (125-200 m), the youngest formation of the Chilhowee Group, is a thin-bedded to massive buff and blue-gray to white sandstone and quartzite with a few thin beds of shale (Spencer, 1992). The clastic rocks of the Cotoctin Formation as well as the Chilhowee Group are indicative of clastics associated with rift basins. Also of note is a ductile deformation zone (DDZ) which is a braided zone of mylonite, and cataclasite running perpendicular to the Beverlytown traverse. This zone is approximately 100 yards wide and is highly deformed.

## FIELD METHODS

Along with two other colleagues I collected magnetic total-field values with a proton precession magnetometer in three separate areas. The approximate location of our work is between 79°13' and 79° 20' west longitude and 37°35' and 37°42' north latitude. These three areas are: (1) the Oronoco area, (2) the Lynchburg Reservoir area, and (3) the Beverlytown area. A total of 23 traverses were completed over a three week period. Diurnal variation was determined by taking readings of a base station at the beginning and the end of each traverse. The diurnal variation was +/- 0.75 nT/ 15 minutes.

Traverse lengths ranged from approximately 3,000 feet to approximately 20,000 feet with a reading was taken every 100 feet. When a large anomaly was recorded between consecutive stations, reading intervals were changed to 25 feet in order to more completely define the point at which the large anomaly occurred. Culverts, piping, metal guard rails, telephone and power wires were noted and readings within 25 to 50 feet of these disturbing influences were discarded because of the anomalous readings they created.

dissolution within the microlithon. The presence of the six smaller planes of cleavage confirms that shortening through dissolution did occur within the microlithon. Therefore, the percentage shortening on this scale is only a minimum. Again, shortening at this scale is not considered in calculations in scales of meters or kilometers. Another shortcoming of dissolution calculations is the relocation of the material that is treated as, essentially dissolved mass. These calculations only consider a two dimensional plane of dissolution while in fact, dissolved material remains in the system.

Deformation in the MBR sheet in the hangwall of the SPT was characterized by isolated small scale ductile deformation amidst large thrust bounded structure. The ductile style of deformation indicates great pressures and is evident by the presence of sheath and ptigmatic folds (see figure 3). Because of the ductility of the deformation shortening was examined at a more detailed scale by examining centimeter scale folds of the Cambrian Conococheague limestone. The fourth scale is in the order of magnitude of centimeters on the outcrop. Deformation of units in the hangwall of the SPT are characterized by large anticlines and synclines with isolated intense areas of micro structural deformation in hinges of folds. Photos were taken within 100 m of each other along fold axis in a hinge of an anticline. Twenty five micro units were measured in the photographs and retrodeformed. Shortening calculations indicated average shortening of 67.9 %, with as much as 94.2% and as little as 33.8% shortening occurring in micro units. Samples for thin sections were taken in this area and will be examined with the aim of calculating percentage shortening at a microscopic level.

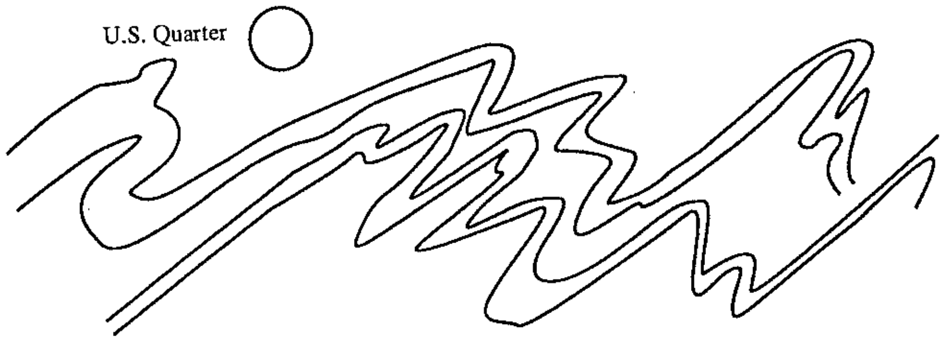


Figure 3. Trace of ductile micro units within a fold hinge in Cambrian Conococheague limestone.

## CONCLUSIONS:

1.) At a macroscopic scale (in kilometers), 48% shortening was calculated for the Ordovician Lincolnshire and New Market limestones.
2.) At outcrop scale (in meters) 54% shortening was calculated for the Ordovician Edinburg limestone.
3.) 23% Shortening through dissolution was calculated for the Edinburg limestone.
4.) 67.9% shortening was calculated at a centimeter scale for the Cambrian Conococheague limestone.
5.) Large scale interpretations of percentage shortening within thrust sheets cannot be accurate unless a spectrum of micro to macro structures are analyzed.
6.) Percentage shortening in general will be greater than predicted in the Central Appalachians due to penetration of deformation.
7.) SPT hangwall deformation is characterized by intense isolated micro structure amidst large scale structure.
8.) SPT footwall deformation is characterized by meso and macro scale structures.
9.) Assuming consistent bed thickness is problematic, considering the amount of meso and micro structural deformation and dissolution that has occurred in the units within the study area.

## REFERENCES:

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## DATA CORRECTION AND REDUCTION

### Diurnal Variation

Field readings recorded from each traverse were corrected for external effects in preparation for analysis and modeling. The first correction determined was diurnal variation. Using the values from re-zeroing at the base station, variations of total magnetic field at one station over the course of the day were used to calculate the rate of change in the magnetic field of one particular station per 15 minute interval. This rate was used in adjusting readings to take into account the diurnal variation.

### Geographical Variation

The value of the Earth's total magnetic field at each station was subtracted from each field value. A rectangular map was drawn to encompass each traverse. Values of the main magnetic field of the Earth at each corner of this rectangle were supplied by the National Geomagnetics Information Center in Denver, Colorado. This information provided the rate of change in the Earth's magnetic field over a specific distance. This was used to determine total-field values for each station. These were then subtracted from the measured values.

## MODELING

After correcting the magnetics data for diurnal variation and geographical variation, final magnetic anomaly values were plotted for the Beverlytown and Lynchburg Reservoir traverses. Magnetics modeling was then undertaken to determine if the observed anomalies could be correlated with greenstone exposures in the Lynchburg Reservoir traverse and if the anomalies observed in the Beverlytown traverse could be correlated to buried greenstones.

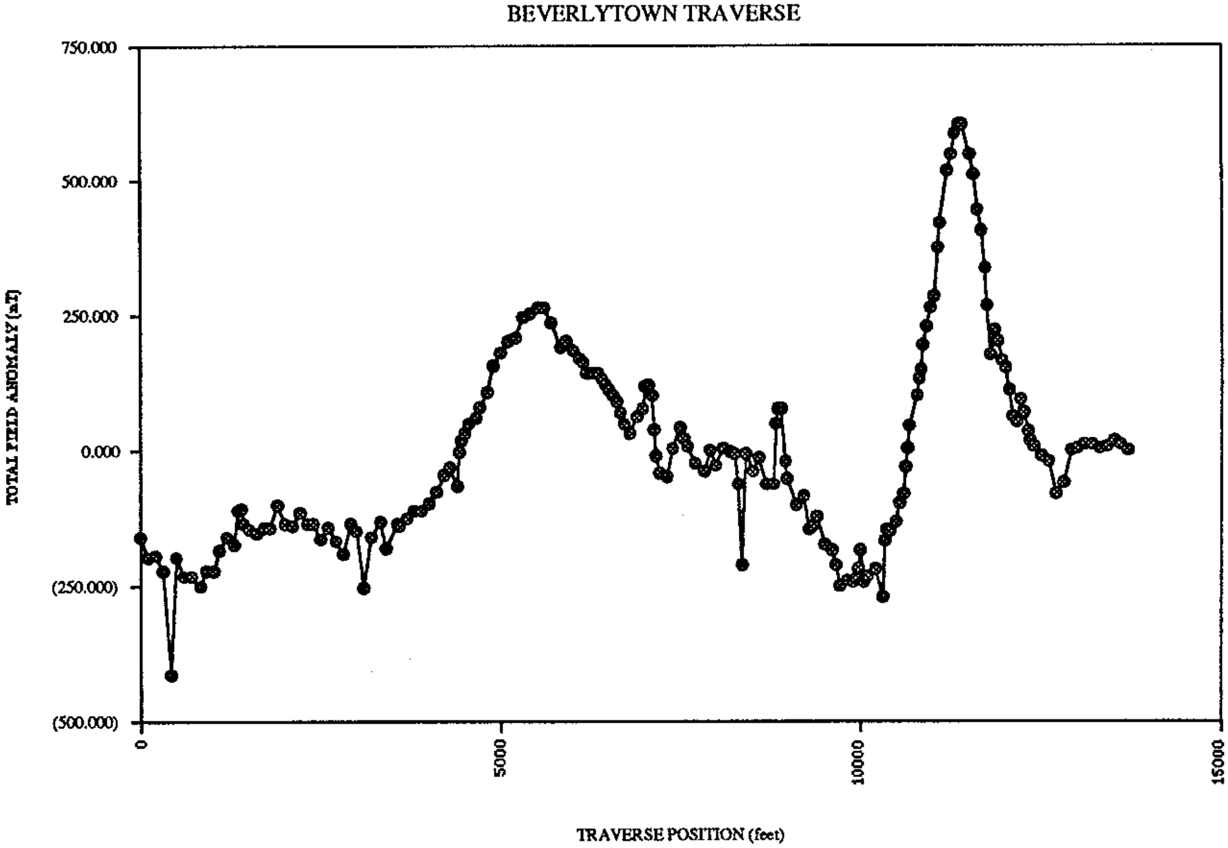


Figure 1. Total-field magnetic values in nanotesla along a traverse in the Beverlytown area.

Modeling parameters were: (1) intensity, inclination and declination of the Earth's magnetic field: 54000 nT, 67°, and 8°; (2) profile orientation: 135°; (3) greenstone magnetic susceptibility: 0.005 cgs emu; and (4) greenstone inclination: 75-90°. Magnetic susceptibility values were not available for the greenstones, so a value of 0.005 cgs emu was selected which is in the range of susceptibilities for gabbros and basalts.

Greenstone dips in the study area are dominantly very steep, and as subsurface relations are unknown, polygon dips were oriented at various steeply dipping angles ranging from 75° to vertical.

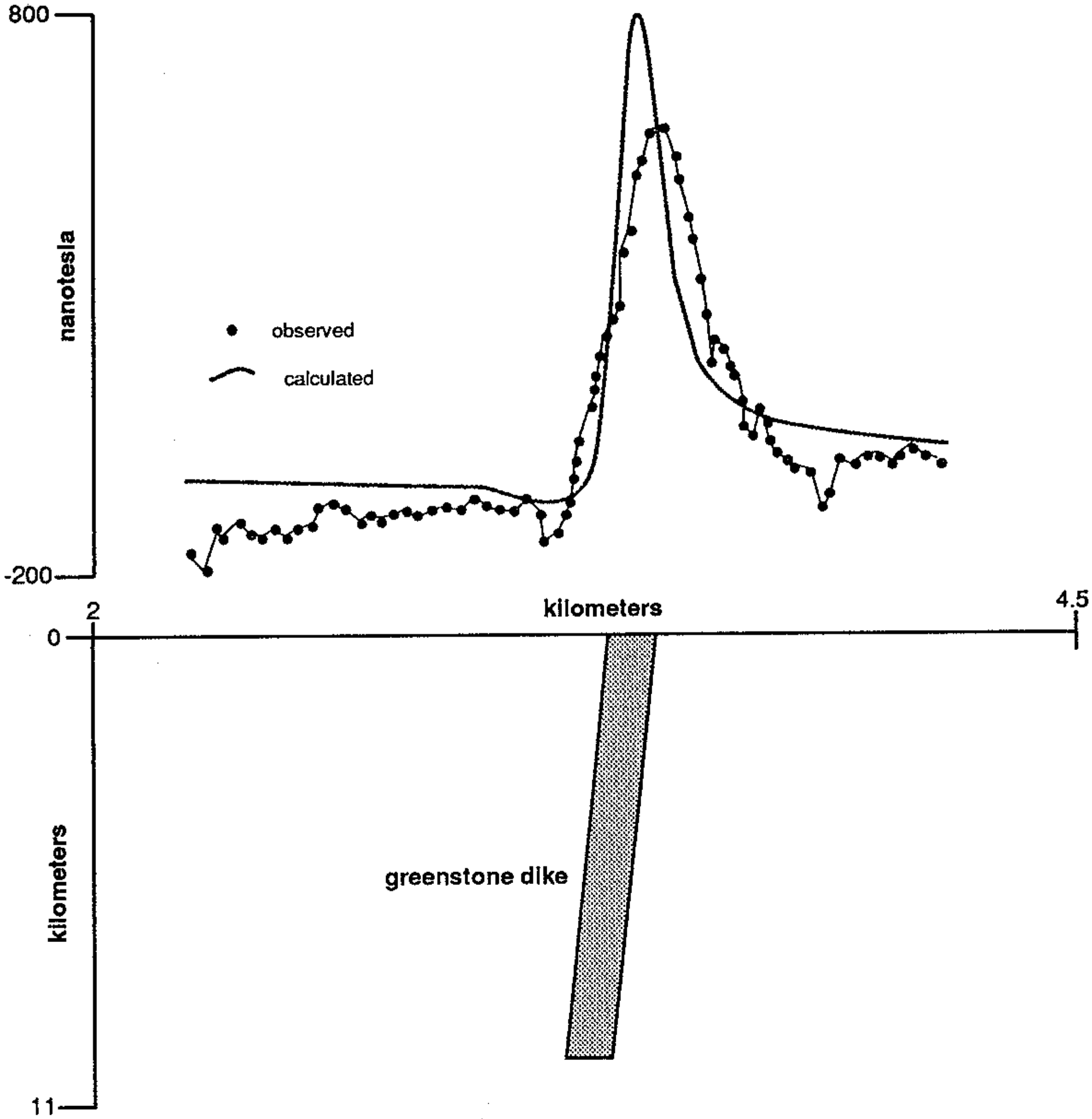


Figure 2. Magnetic total-field curve computed for a steeply dipping greenstone dike compared to observed total-field anomaly along the Beverlytown traverse.

## DISCUSSION

The rock units in the Lynchburg Reservoir area, specifically the Cotoctin greenstones, are well exposed and mapped. This traverse has rapidly varying, total-field anomaly readings. An examination reveals a decrease followed by an increase of 3000 nT. This rise at 1500 feet coincides with a suite of closely spaced greenstones. Correlation of greenstone exposures and the magnetic traverse suggests that rapidly varying readings with ranges of 1000 nT apparently are related to the greenstones. A magnetic model substantiates the correlation between the greenstones and these 1000 nT anomalies. When several closely spaced greenstones were modeled using closely spaced, steeply dipping polygons, it proved impossible to match anomaly curves exactly, but the general magnitude and broad dimension of anomaly and model curves are similar.

The Beverlytown traverse has fewer exposures of greenstone. Covered primarily with the metasedimentary rocks of the Chilhowee group, there is little reason to expect significant anomalies. However, the total-field curve for this traverse illustrates anomalies of approximately the same magnitude as those at the Lynchburg Reservoir (Fig. 1). The largest anomaly begins at a traverse location of 10,000 feet. This coincides with the DDZ. As this is simply a zone of deformation, it is difficult to explain such a large anomaly. This 2400 nT rise is on the same scale as that produced by the Cotoctin greenstones at the Lynchburg Reservoir. This would suggest that perhaps there are buried greenstones intermixed with the metasedimentary rocks of the Chilhowee. Figure 2 illustrates that a greenstone dike models the anomaly size and shape quite nicely.

## CONCLUSIONS

Exactly modeling the closely-spaced suite of Cotoctin greenstones proved difficult. Though one outcrop of greenstone could be effectively modeled, more than one outcrop could not. Some of this difficulty arises due to the uncertainty of the structure at depth as well as susceptibility magnitudes and variations.

The most successful aspect of this project was the specific correlation of greenstone outcrop and magnetic anomaly curves which provided a standard for suggesting the presence of subsurface greenstones. The rocks that outcrop along the Beverlytown traverse are not highly magnetic, but significant magnetic anomalies are present in the area. The fact that greenstones outcrop directly north of the traverse and that the anomalies are strikingly similar to the greenstone anomalies at Lynchburg Reservoir suggests greenstones are present at depth along the Beverlytown traverse.

Using magnetics as a mapping tool is helpful in that it demonstrates the presence and location of magnetic units in the subsurface On the other hand magnetics is less useful for mapping exact locations of closely-spaced, highly-magnetic, suites of rock due to the complex anomaly patterns such geometries produce.

## REFERENCES CITED

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# Structural Interpretation of Rockbridge County, VA
# Central Appalachian Valley and Ridge Province

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## Introduction

Balanced cross section methods can aid in structural interpretations of fold thrust belts where data are absent or insufficient for subsurface constraint. Line length and/or area restoration ensure that a section is balanced: one that is geometrically correct and restorable to it's initial state through kinematically reasonable steps (Mitra, 1992). This approach at least ensures that the interpretation is a realistic possibility. Restoration does not imlpy a correct interpretation, but rather establishes a reasonable origin. Balancing techniques are best applied to deformation which is confined above a basal detachment, such as the Canadian Cordillera or the Appalachian orogen.

The Central Appalachian Valley and Ridge is a blind-thrust terrane characterized by plunging anticlinoriums and synclinoriums. The purpose of this project was to use balancing methods to aid in the construction of a cross section through Rockbridge County, Va., 35km northwest of Lexington. Surficial geologic mapping and a unpublished seismic profile across an 20km transect were used in conjunction with data and interpretations from adjacent structures. Subsurface structures were thus interpreted from surface outcrops, basement depth and the proximal deformation style.

## Deformation Style and Previous Investigations

COCORP, USGS, and private seismic reflection profile interpretations, and drill hole data have led to the general acceptance that crystalline basement was not directly involved in Appalachian foreland deformation (Perry, 1975). The thrust fold belt was first recognized to deform by décollement (detachment) and overthrusts by Rich (1934). The sedimentary column has since been divided into three competent and two incompetent lithotectonic units (fig. 1) which partially control the deformational mechanics and structure of the Appalachians (Jacobeen, Kanes, 1974). Décollement in the Waynesboro and Martinsburg shales formed two chronologically and structurally distinct thrust sheets. Deformed rocks above the Waynesboro and Martinsburg décollements will be referred to as the Waynesboro sheet and the Martinsburg sheet, respectively (fig. 1).

The upper-level detachment in the Martinsburg occurred before the lower Waynesboro décollement (Perry, 1978; Kulander, Dean 1986). The present structural style of the Martinsburg sheet is dominated by short-wavelength, asymmetrical, overturned folds, and forelimb and backlimb thrust faults (Kulander, Dean, 1986). The later, deeper-seated Waynesboro décollement thrust the lower competent unit of Cambrian-Ordovician carbonates into duplex geometries (Evans, 1989) and further displaced the overlying Martinsburg sheet, creating a complex deformational history. Imbrication in the lower thrust sheet is interpreted from extensive seismic studies, structural culminations, and deep well data. These lower thrusts deform the Cambrian-Ordovician carbonates into fault-bend and fault-propagation folds (Evans, 1989) which are exposed in places in the Valley and Ridge. In Pendleton County, Va., 70km from the study area, the Ray Sponaugle well penetrates the Wills Mountain Anticline (Perry, 1975). Drill hole and seismic data indicate that the structure developed as a fault-propagation fold along a detachment in the Martinsburg at 3300m depth. This characteristic blind thrust terrane is continuous throughout the Valley and Ridge.

## Field Area and Investigation

Immediately west of the Great Valley, the Maury and Cowpasture Rivers slice through the easternmost folds of the Valley and Ridge. The lower, Waynesboro thrust sheet is not exposed here, so data from proximal studies were used to aid in modeling the lower deformation. Field investigation along the 20 km transect involved mapping the exposed Martinsburg sheet; upper Ordovician through Lower Devonian carbonates, shales, and sandstones (fig. 1). Bedding orientation, faults, fold axis, and fold styles were recorded in detail to provide for cross-section control.

The principal structures, three anticlinal ridges of Silurian orthoquartzite separated by two broad valleys of Devonian shale, are structurally distinct. The orthoquartzites of the eastern anticlinorium are displaced by two northwesterly dipping backthrusts. The eastern backthrust was evident from repetition of Silurian units. The Western backthrust is well exposed and also repeats the breadth of the orthoquartzites. The western anticlinorium is tightly folded and overturned to the northwest; it's forelimb is thinned and dips 55° southeast. The Tuscarora formation exposed in the core displays kink geometry and disharmonic folding, causing variable bed thickness. Elsewhere, all competent units exhibit kink folding